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ABSTRACT

This paper discusses current theories of learning and their application to engineering education, particularly in Latin American nations. The principal objective is to show methods by which insight can be gained into human learning, particularly in the engineering colleges. The development of more effective engineering teaching remains a necessary task. Few institutions have done something to improve the quality of learning and to raise students' motivation. The theories of Ausubel, Novak, and Gowin are examined. The paper assumes two fundamental premises: (1) the nature of classroom learning and the factors influencing that learning can be unquestionably determined; and (2) such knowledge can be both systematized and transmitted to prospective professors. The paper concludes that engineering teaching changes are realizable when powered by a comprehensive theory of education and a constructivist point of view. (Contains 31 references.) (WRM)

THE GLOBALIZATION AND THE ENGINEERING TEACHING FOR THE XXI CENTURY

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ABSTRACT: Nowadays, it is well known that Latin American R&D investment represents only the one percent of the world assets. We also know about the fiscal restrictions that limit Latin American public investment. At the same time, our companies face rigorous international competition. In the mentioned frame, Latin American universities constitute the obligated means to help society to overcome this situation, by mean of increasing both student creativity and the innovation criteria. In order to achieve that goal, universities must look for research excellence, guided mainly by society's demands. These goals can only be achieved if engineering teachers take the commitment to participate in the ongoing process of change, in order to encourage the necessary changes in the students' formation. To do so, instead of dominance of content selection, the students' needs and interests regarding the knowledge generation must be taken into consideration. We understand globalization as a promissory way to promote meaningful learning. From this point of view, we propose a new way to face Engineering Science Teaching.

Introduction

The principal objective of this article is to show some methods by which we can gain insight into human learning, particularly in the engineering colleges. The use of experimental approaches to instruction raises social and political issues. In the recent years some of the best minds in education have been engaged in policy studies. The complex problems of schools administration, local, state, and federal tax support for education and the relationship of schooling to economic growth are indeed a fascinating challenge. The major defect in most of the writing on educational policy is that, they fail to recognize that our primary concern is with human learning.

Instructional development at engineering college can have multiple goals and objectives, it is usually measured based on a single criterion: efficiency. We think that success or failure in efforts towards instructional development should only be judged to the extent that these efforts contribute to increase both, efficiency in the classroom and the relevance of the skills and knowledge produced to the labor market and other social requirements. This work gives priority consideration to the instructional effects produced by a new instructional model.

It should be noted that often, economists feel that instructional development occurs as a phenomenal exercise conducted by evangelical advocates of particular methodologies, without appropriate concern for the specific fiscal and labor market environments within which the educational enterprise must operate. In addition, they pay inadequate attention to earlier lessons and the possible transference of existing instructional systems. In fact, there are two ideological points that divide economists from instructional developers: a) the possibility of quantifying the costs and effects of instructional design in comparison with other instructional alternatives, and b) uniqueness versus the idea of generalizing instructional development efforts across regions within a country.

Certainly, these two major ideological differences reflect the nature of training in the two fields. Instructional development training is heavily rooted in cognitive psychology and places a premium on the perception of the individual and unique needs of the student. In contrast, economists refer to the individualistic science that is dependent upon the laws of large numbers. However, the application of economic analysis to education is often a stochastic one, that is, based upon probable behavior. Thus, the question of measurability and of uniqueness underlies the gap that exists between those who develop educational systems and those who are increasingly being asked to analyze them.

In his report of some investigations on "Teaching Introductory Physics to Students of Engineering and Science at Cornell", D. F. Holcomb (1978) wrote: "The development of more effective teaching is a difficult business. One of the central problems is the difficulty in assessing whether one has *improved* the quality of instruction in any given course when one makes a change in any of the main ingredients -subject matter and teaching materials, chosen mix of student's activities, or instructional format-. Any improvements which may be made are nearly impossible to validate convincingly because of the multi-variable nature of the problem. Thus, one is frequently reduced to reliance on intuition, subjective intellectual taste, and imprecise observational tools in deciding whether a certain change is expected to or has in fact improved the quality of instruction."

A feasible alternative is "theory driven" change; if the theory is viable, many improvements can be achieved. Many classroom practices in introductory physics courses, however, have little to do with theory based instructional methodologies. An important task for engineering teaching is to find

activities that allow students to acquire meaningful learning (Ausubel D. et al, 1978). Instruction that does not take meaningful learning into account is totally ineffective for students.

Particularly, in teaching engineering courses, teachers must have more than dedication and good knowledge of the subject matter. They also have to know how students learn, and also what this work is trying to address: to supply some knowledge about how new concepts are learned and provide some instruments to help both, teachers and students to accomplish meaningful learning. Naturally, the current situation in engineering courses is a very serious problem, but we think that significant progress can be achieved by means of "theory driven" engineering education research and instructional design.

We believe that the development of more effective engineering teaching remains a necessary task. Still, few institutions have done something to improve the quality of learning and to raise students motivation. And this is where attention must be concentrated on, trying to direct efforts adequately.

As a matter of fact many interested teachers want to reduce the influence of the inefficiencies experienced in these courses, especially those related to the instructional format offered to many of them; but they often find themselves helpless to manage it in the classroom. It is the intention of the present work: to demonstrate that, by reducing rote learning and increasing meaningful learning, many of the problems could automatically disappear. As a consequence, the instructional efficiency may be greatly improved. It is the second objective pursued in this work to somehow illuminate this field of investigation and to make proper tools available to other interested teachers. With the intention of achieving the above stated purposes, this work is based on Ausubel/Novak/Gowin's theory of meaningful learning. Some essential features of these theories are introduced below, where an attempt to propose an instructional model will be made, based on both the meaningful learning theory of education and classroom experiences.

We will assume two fundamental premises: 1) the nature of classroom learning, and the factors influencing that learning can be unquestionably determined 2) such knowledge can be both, systematized and transmitted to prospective professors.

A word of caution is necessary here. In any case, instruction in the principles of classroom learning is a necessary, but hardly a sufficient condition for becoming a good professor. Other prerequisites, in addition to initial aptitudes, include **interest, commitment and motivation. Training in the methodology of teaching a particular subject matter is equally important**. Professor's practice both on educating and doing research on education must be governed by the same set of congruent theories. Thus, one major point is the suggestion that theories of education supply practical solutions to the multiple problems of engineering science teaching. New practices and new concepts come from new thinking theory stimulus.

Another major point is to suggest that educational epistemology also supplies solutions to these problems. By understanding the knowledge structure of subject matters (mathematics, chemistry, physics etc.), students, professors, and researchers have a way of knowing those help increase students' learning.

THEORETICAL FRAMEWORK : THE AUSUBEL/NOVAK/GOWIN'S THEORY OF MEANINGFUL LEARNING.

The central idea in Ausubel's theory is that of meaningful learning, which he defines as "non-arbitrary, substantive, non-verbatim incorporation of new knowledge into cognitive structure" (Ausubel, 1968). This means that the learner must make a conscious effort to relate (integrate) new knowledge to knowledge s/he already has. For example, a student learning new information on centripetal acceleration would consciously relate this material to what s/he already knows about acceleration in general.

Meaningful learning involves the linkage of new information with a specific knowledge structure, which Ausubel defines as subsuming concepts or "subsumers", existing in individual's cognitive structure. In kinematics, for example, if the concepts of vector and scalar already exist in the learner's cognitive structure, they serve as subsumers for new information concerning a certain type of vector and scalar quantities, e.g., velocity and speed. Thus, during meaningful learning, new information is associated with existing relevant subsumers in cognitive structure. This association, in turn, results in further growth, and transformation of the subsumers which can be relatively large and well developed or limited and poorly developed, depending on the frequency that meaningful learning occurs in conjunction with a given subsumer. In this example, an intuitive idea of speed would serve as subsumer for new information concerning the motion of particles.

Ausubel uses the concept label subsumption to represent the idiosyncratic nature of meaningful learning and the fact that new knowledge is usually incorporated (subsumed) into more general concepts. Each person's cognitive structure is unique, and consequently subsumption of new knowledge produces a cognitive interaction product that is dependent both on what concepts or misconceptions the learner already has and the material presented. Ausubel distinguishes between meaningful and rote learning. Rote learning occurs when relevant concepts, or subsuming concepts do not exist in the individual's cognitive structure, or the learner does not choose to relate new ideas to relevant concepts s/he possesses. In such a case, new information must be arbitrarily stored in the cognitive structure. It means that it is not linked with existing concepts or, in other words, it is rote learned. An obvious example

of rote learning in kinematics, is the rote memorization of formulae. For example if the general ideas of acceleration and velocity were not available in the learner's cognitive structure, he could only rotely learn that acceleration is the rate of change in velocity and velocity is the rate of change in displacement. S/he could memorize this, but, according to Ausubel, it would not result in acquisition of new meanings.

According to Novak (1977), rote learning is necessary when an individual acquires new information in a knowledge area completely unrelated to what s/he already knows. In these cases, Ausubel would recommend the use of advance organizers. They are small learning episodes more general and more inclusive than the learning material that follows and they are perceived by the learner as a cognitive bridge between what s/he already knows and what is to be learned. Contrary to summaries and overviews, which are ordinarily presented at the same level of abstraction, generality and inclusiveness simply emphasizing the salient points of the material, organizers are presented at a higher level of abstraction, generality, and inclusiveness. Organizers are selected on the basis of their appropriateness for explaining, integrating, and interrelating the material they precede. They also serve to facilitate linking new knowledge to relevant related prior knowledge.

In Physics, for example, when introducing the learner to a new sub-discipline like Newtonian mechanics, a general discussion about the situation of this new area in the whole context of the discipline would serve as an advance organizer for the new information. In this respect, exceptionally difficult is the problem that arises in introductory physics courses when students link new physics knowledge to "common sense" concepts (subsumers) they already possess. Regarding this issue Lorenzo (1992) stated: "Most of the misconceptions, especially in physics, are based on the fact that students have, without prior instruction, a broad system of common sense beliefs about the physical world constructed from their everyday experience. These beliefs are mostly incompatible with the scientifically accepted concepts and limit the possibility to perceive the world in a scientific manner. Therefore, misconceptions must be recognized as a tremendous problem in science learning". Moreover, she also explains mispropositions, which can be defined as the false or incorrect relationship or link between concepts. However, while we say that the relationships are false, from the students' point of view the relationships are really true and plenty of meaning. Hence, we can conclude that mispropositions are propositions not scientifically accepted, but meaningfully learned. Finally she also introduced the word "No-propositions" which she defines as "The absence of relationships between concepts that should be interrelated." The presence of these so-called no-propositions is evidence of another case of rote memorization, because the concepts have no link with the learner's subsumers.

TWO IMPORTANT PRINCIPLES OF AUSUBEL'S THEORY: PROGRESSIVE DIFFERENTIATION AND INTEGRATIVE RECONCILIATION.

The principle of **progressive differentiation** states "The meaningful learning is a continuous process wherein new concepts gain greater meaning as new relationships are acquired". According to that, the most general and inclusive ideas of the discipline should be presented first, and, then, progressively differentiated in terms of detail and specificity. Following this principle in an example of physics, acceleration has to be introduced, at the beginning of the explanation, in order to serve as conceptual "anchorage" for subsequent presentation of motion of particles. Traditional instruction would follow the content organization found in most textbooks on the subject, which starts with reference frame, distance, displacement, velocity and finally acceleration.

Still, other authors have argued that not only the knowledge is structured, but also the instructional sequence must be accordingly organized. Furthermore, they say that in order for the learning to be successful, the curriculum must have a hierarchical organization.

The principle of **integrative reconciliation** states that "Meaningful learning is enhanced when the learner recognizes new relationships between related set of concepts or propositions".

This principle is also used in the organization of our instructional model. According to that, for example, force and acceleration are not studied separately: they are related from the beginning. We think that this principle is really important in engineering teaching, where the concepts are very interrelated to each other. So we emphasize that we have tried to arrange the content of each unit in a sequence according to this principle (which is not necessarily the sequence found in most textbooks).

For example, a classical sequence for an introductory course in kinematics at college level starts with reference frame and displacement, then goes into velocity and speed and ends with acceleration. The concept of displacement, which is a key concept, but highly specific, is at the beginning of the sequence, and acceleration, which is the general concept describing kinematics phenomena, is at the end. In a sense, this sequence is exactly opposed to Ausubel's theory because it starts with the specific and ends with the general, whereas in accordance with the principle of progressive differentiation, the most general and inclusive ideas should be presented first.

Basically, this "experimental" instructional model consists of starting the course with the more general phenomena and concepts of kinematics and progressively differentiating them. We include the term force in the study of kinematics because -being the key concept in dynamics- it is an essential concept that we need to explain motion. The acceleration concept is introduced at the beginning of the course because we take into account this physical quantity as the most inclusive one. Then, we introduce the

concept of velocity, speed, reference frame, position vector, and displacement. In order to do this, we propose the idea of step by step concept learning sequence which consists of studying the meaning of each key concept very carefully, one by one, prior to defining each of them by means of a mathematical expression (formula). Once the students have grasped the meaning of those concepts, they are discussed with more specificity.

After that, it would be convenient to follow the traditional sequence from more specific to more general concepts to give a mathematical definition of each concept using formulae and calculations. This represents the greatest degree of detail. This instructional proposal consists of "cycling" or going "up and down" from more general to more specific concepts, and "backing up" again as it is recommended by Novak (1977).

In summarizing the scope of these theories, we can say that education is viewed as changing the meaning of students' experience, by means of empowering professors and students. Within this theoretical framework, the construction and use of three meaningful learning tools have been described by Novak and Gowin in their handbook Learning How to Learn (1984): they are the so called "metacognitive tools" e.g. concept mapping, Vee diagramming, clinical interviewing. A brief description of them is given below.

GLOBALIZATION AND INTERDISCIPLINARITY

There are differences between universities and the business world. The globalization of business means, that survival of business require rapid, effective and efficient new learning and new knowledge creation. It is possible then, that many business become knowledge creating organizations, and the principles of meaningful learning be accepted more rapidly in the business than the academic world.

We may point out that even today there is a great confusion in the educational arena as regards the following concepts: Globalization, integration and interdisciplinarity. This problem arises as a result of their theoretical-epistemological conceptions.

All-pervasive influence of positivism is still felt in education; consequently, behaviorism is a part of our classrooms. Behaviorism postulates that stimuli should be isolated and presented in a recursive fashion, this would lead to learning by means of repetition of the proposed content. Thus, the subject matter was divided and parceled into areas or subjects, and these, in turn, into units or modules, etc. Our proposal not only requires this atomization to stop, but also demands a full **integration** of this now isolated pieces.

Globalization of education then is understood as considering that meaning, to a person, is always a function of how he or she has experienced the combination of thinking, feeling and acting throughout life experiences. We can argue that, in this way, learning is the constructive **integration** of thinking, feeling and acting, having the second meaning of integration

In this framework, **globalization** consists of organizing teaching in such a way that it promotes meaningful learning. This implies the fact that students' needs and possibilities will prevail over content.

The subject matter becomes secondary in the globalization enterprise, which aims at a different attitude that leaves obsolete ideas behind. The teaching-learning process should be re-organized taking as basis the students' cognitive structures.

Instruction, whichever the area, may be structured around a penetrating-transversal topic, which must be contextualized, so that it allows the students to establish meaningful links. It should be taken into account that we aim at an instructional model that is based on students' needs and ambitions, though pedagogically oriented by the professor. Thus, it may be claimed that global learning is highly meaningful. This makes concept maps a useful tool, not only for professors in the planning and evaluating stages but also for students, in the comprehension of texts.

Finally, the concept of **interdisciplinarity** underlies the fact that the subject matter by no means can be presented in an isolated fashion. Subjects must always be related among them. Therefore, relationships among subjects must always be shown. It is invariably possible to find relationships among the different topics of physics, biology, chemistry etc.

THREE MEANINGFUL LEARNING TOOLS:

(A) CONCEPT MAPS

It can be said that, in a general sense, concept maps (Novak, J.D. & Gowin, D.B., 1984) are just diagrams indicating relationships between concepts. However, more specifically, they are hierarchical diagrams that attempt to reflect the conceptual organization of the structure of knowledge. Also, concept mapping is a powerful tool that can be used in great variety of situations for very different purposes, such as teaching strategies, a means of evaluation or a curricular design tool.

A concept map is an analogue to a road map in that it not only identifies the major points of interest (concepts), but also illustrates the relationships among the concepts in much the same way that links among cities are illustrated by highways and other roads.

A concept map also has a hierarchical structure. Concepts are enclosed in boxes and connected by lines. Relationships between concepts are made explicit by the use of linking words on the lines. They are intended to represent meaningful relationships between concepts in the form of propositions.

If the concept map maker labels the lines connecting concepts with one or more words in such a

way that the concepts and the linking words form a proposition, his/her map would represent not only his/her own way of organizing a given set of concepts but also propositions that express the cognitive meaning assigned to relationships between concepts. As such, concept maps might be seen as a strategy for externalizing one's conceptual and propositional understanding of a piece of knowledge. Moreover, if this is true, when drawing a concept map the learner is likely to externalize his/her misconceptions and misunderstanding as well. Because of this, it can be said that concept maps are a powerful evaluation tool.

Are concept maps and flow diagrams the same thing? The answer is No. Flow diagrams indicate some form of logical order or time sequence, while concept maps indicate the conceptual framework of somebody's mind. They are constructed to indicate the different relationships between concepts (e.g. propositions).

(B) VEE DIAGRAMMING

Since the concept globalization of learning supposes a reflexive and critical approach to the subject matter contents, starting from a focus question (or central problem), the students will perceive the usefulness (or global capacity) of the Vee while using this tool, according to their own cognitive capacities.

Vee diagramming is a way to represent the dozen or so major epistemic elements arrayed around a Vee. Most scientists and mathematicians recognize the relevance of epistemic elements such as "theory," "concept," "event/ object," "fact," and "knowledge claim." Students (and their professors) can be taught in a brief period of time to name these epistemic elements and to see the connections between elements. Students, then, begin to conceive the structure of knowledge (structure elements and their relations to each other). Misconceptions can be located at the connections between epistemic elements. It is a faulty relation between pieces of the structure of knowledge that permits misconceptions to persist so strongly. The remedy then is to help both professors and students to reconstruct prior knowledge. The Vee diagram analysis technique helps learners to move <u>between elements up and down</u>, across, and between elements. This process of reconstruction of claims to knowledge is a primary learning process. This tool is broadly explained within the already cited Novak & Gowin (1984). Moreover, there are many works that demonstrate the efficiency of the Vee; Some authors showed the vital connection between active learning and responsibility. In a year-long biology course, students instructed in the use of the Vee diagrams were found to be "on task" in labs upwards of 90-95% of the time. Follow up interviews showed evidence that these students felt more responsible toward their own learning than before; the Vee empowered them to take charge of their learning.

(C) CLINICAL INTERVIEWS

"The origin of the interview go back to the nineteenth century work of psychoanalysts, although forms of systematic questioning were used in early Greek and Roman times, or before" (Novak-Gowin, 1984, p. 119).

The main objective of the interview is to ascertain what the student already knows regarding a particular body of knowledge. With this information we can start to select and to organize the most adequate examples and concepts for the instruction process based on student's prior knowledge, which is in the core of globalization conception. After the instruction, we can measure the effectiveness of this instruction and share the meaning with the students.

By means of the interview, it is possible to "look into" the student's mind and then to explain the cognitive structure, not only the concept and propositions that they have but also how they are structured and how they can be used in the problem solving task.

It can be said that, by means of an interview, we construct events with the students. The records obtained will depend on the task presented, and the questionnaire we have prepared.

Also, it is useful to combine the planning of the interview with the construction of a concept map to identify key concepts and propositions.

Finally, it will be indispensable to take into account that the cognitive structure of a human being is so idiosyncratic, that the interview will seldom make known exactly the student cognitive structure. Nevertheless, we can get an immense quantity of valid data concerning what the students know and how they use their knowledge.

THE INFLUENCE OF EDUCATIONAL EPISTEMOLOGY

To educate, in the view of this theoretical framework, is to change the meaning of experience. Can we do it? Is engineering teaching reform possible? Yes, we can change and reduce misconceptions.

Educational epistemology is not sufficient, however. We need to coordinate it with theories of educating and to bring in explicitly Principles of Educating. According to Novak, we can organize principles into the five factors involved in every educational event: professor, learner, knowledge, context and evaluation, all in accordance to our concept of globalization and its relation with meaningful learning.

In order to find solution for instructional problems, we must rely, as it was said, on plausible educational principles (Novak, J.D., 1998).

Another important principle we have accepted states that all **five factors must be considered together.** No good reform of engineering teaching will occur by just researching one of these five. For example, the psychological scientific studies of learning tell us almost nothing about teaching,

knowledge, or context. The 100-year search for scientific laws of human learning is a complex history of failure. There are no laws of learning of the sort found, for example in thermodynamics. We generalize from this history of failure in social science research to say that the natural science model of research is a poor choice for social and educational research.

Here, then, is another misconception, located in the philosophy of science. It is easy to see but difficult to change the fact that science and math professors and other professors who use the dominant epistemology model of their subject matter to study educating are going to fail to find out much about educating.

The key is to pay attention first to all events of educating themselves. We must begin with educative events of teaching, learning, knowledge, context and evaluation. Not, as usual, with Science (or Math) Teaching, nor the Epistemologies or Philosophies of Science or Mathematics.

To the extent we can accept this starting point, then the next step is to take a look at the above mentioned learning principles (subsumption, progressive differentiation, integrative reconciliation etc.).

HOW TO EMPOWER PROFESSORS AND STUDENTS IN CLASSROOM

To empower professors and students is one of the most important points to be achieved. Here we summarize what Gowin states as the three levels of educational episodes:

Level 1:

a) **To help students to trust their own experience.** The first Gowin's concern is to help students and professors to trust their own experience. He tries to validate their own prior knowledge. He tries to get them to "put something on the table" so professors and students can begin to negotiate and share meaning.

b) **To give students something to do**: Right away, they can make concept maps from something in their experience that they know very well. Their prior knowledge gets expressed through concept maps. They begin to learn new ideas by using them heuristically in their own fields. Having something new to do underlines the importance of making events to happen. The concept map technique not only is something new to do, it also validates students' knowledge and gives them a new power over their own minds. Sometimes, this experience is marked by a feeling of frustration and agony over inadequacies. But it always helps them realize they have power over their own learning, indeed, **no one else can learn for them**. The professors do not cause their learning. This insight usually releases energy and results in great diversity of student's responses. Gradually we all begin to realize we each organize our conceptual images differently. Perhaps we realize it is because of our past that we each have largely idiosyncratic experiences. Learning and knowing that experiences are truly ours and different from other persons, but these differences can readily be shared through language and educating. Such diversity is to be prized. Experience can be shared, and that makes educating possible.

c) **Take your time**. Learning about learning takes time. All learning takes time. And the time it takes is different for all learners. Time is a tyranny in most organized schooling practices. Usually time is used to control effort directly rather than to control meaning that controls efforts.

Level 2:

Analyze other people's works. This level requires students to become competent in Vee Diagram analysis. Then it is good to ask them to go after the major authorities in their field. They could analyze research papers, books, textbooks, philosophies of discipline etc. Empowerment results when they come to understand how fallible and limited expert authority is. Experts disagree among them. Each professor must construct his own curriculum and become his own authority. One among many but stills one.

Level 3:

To help student's self-learning. It begins when students initiate their own research. As they complete this research, they realize their own self-educating. The professors' job is done when theirs is under their own power. Professor-student interviews, audio and video taping are highly recommended techniques, something to do that makes records of new events. These records can be studied together by professors and students. And gradually an educational Vee, a structure of knowledge about educative events, is constructed. As events change in the future, these Vees will also change.

Many studies show the educative value of relating (in a deliberate and explicit way), thinking, feeling and acting (We understand acting as behavior governed by meaning). We can get at thinking through **concept maps**. We can get at feeling through **interview**, video-stimulated recall tapes, and through written materials students give us about these matters.

A WORD ABOUT THE AUTHORITIES

The intent of classroom, lab, studio, fieldwork, etc. should be shared meaning, toward mutual accommodation, toward that secure cooperation that achieves shared purposes. When this ethos is working, then the need for external authority diminishes markedly. For example, a whole change in the quality of educative human experience comes about when we **change our minds** about **professors causing learning**. Professors cause teaching; and learners cause learning. Professors do not cause

learning. Learners must first choose to learn.

A SUMMARY OF THE PROPOSED INSTRUCTIONAL MODEL

This instructional model has been developed specifically for the physics courses, and has been broadly published (Chrobak, 1997 a, b, 1996 b, c & 1995a), however, it is easy to generalize it for engineering teaching due to the close similarities among the engineering subject matter.

Briefly, we can summarize the proposed instructional model, based on the explained theory of education, saying that it is necessary to:

First of all: **Change our minds**. Change from Conventional to Constructivist.
Seek meaningful learning for empowerment.
Teach students to learn about learning.
Emphasize knowledge growth and explanation development.
Emphasize knowledge **about** science, how and why we know.
Remember meaningful learning that requires: (a) relevant prior knowledge, (b) meaningful material, (c) the learner must choose to learn meaningfully.
Promote Thinking, Feeling and Acting.
Modify and adapt prescribed curriculum. Connect curriculum units. Use structure of knowledge, Concept maps, Educational Epistemology, Vee diagram analysis, clinical interviews, etc.
Construct textbooks, syllabi and lab manuals that show levels of intellectual space, and therefore become more conceptually coherent.
Help students make Knowledge and Value claims.
Change system to serve people.

CONCLUDING COMMENTS

Any professor could truly ask: "But, where do you bite the elephant?" "Isn't the problem too big? " "Aren't the required changes too many?" "And the resources few?" etc.

The answer of course is, *you are right*, but we may be more optimistic. We may make changes where we know something. We may change our **ideas** and bear in mind that, as the way of perceiving knowledge is local, reform can occur in each of the five factors involved in every educational event: professor, learner, knowledge, context and evaluation. In the end, that is our work and responsibility.

There is nothing as necessary as reforming **people's attitudes**. Presumably, our own attitudes must change as well.

We believe it is reasonable to claim that engineering teaching changes are realizable when powered by a comprehensive theory of education and a constructivist point of view.

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